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FEATURES OF DESTRUCTION OF THE COAL-ROCK MASSIF SATURATED WITH SURFACTANTS

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ОСОБЛИВОСТІ РУЙНУВАННЯ ВУГЛЕПОРОДНОГО МАСИВУ, НАСИЧЕНОГО ПОВЕРХНЕВО-АКТИВНИМИ РЕЧОВИНАМИ

Purpose. Investigation of the effect of surfactants on the concentration of fine-dispersed dust fractions in the air space of the working area and the character of destruction of a coal-rock massif by the explosion energy to develop an environmentally friendly way of driving mine workings in coal and ore mines.

Methodology. A few series of experimental studies have been conducted in the laboratory conditions to evaluate the effect of surfactants on the concentration of fine-dispersed particles in the air environment as well as the nature of the hard rock and coal destruction caused by the explosion energy by using the developed method of simulation and the test bed for its implementation. With the help of the optical method and the test bed including a polarizing microscope and an integrator, the microstructure and the granulometric composition of the rock and coal dust particles, saturated with surfactants, have been studied.

Findings. The experimental studies were presented assessing the effect of surfactants on the concentration of fine-dispersed particles in the air environment as well as the nature of the hard rock and coal destruction caused by the explosion energy. Processing and analysis of the destruction products by using an optical method made it possible to establish that fragments of the smallest particles, for example, of solid fine-grained sandstone (f=14–15), selected from the main coal seam of the roof C_{10} when sinking the precast drift No.110U (PSP "Dniprovska mine", DTEK "Pavlogradugol") and of the processed surfactant represented by rounded quartz grains (90–99%) as well as of the unprocessed ones – in the form of acute-angled fragments. According to numerous measurements of the fine-dispersed particles in the destruction products of solid sandstones and coal, processed with 10% solutions of sodium bicarbonate ($NaHCO_3$) and soda ash (Na_2CO_3), as well as with magnetized water and lime milk, their granulometric characteristics, such as median and quartile sizes, sorting and asymmetry coefficients have been established. Numerical concentration values of dust fractions in the air space depending on the type of a surfactant have been calculated.

Originality. Having used the developed method for modeling rock destruction, for example sandstones and coal processed by surfactants, it has been found that the average size of fracture particles of 0–100 microns increases 1.2–1.9 times. In the destruction products of coal samples, processed with lime milk, the fragments of quartz are absent but they are present in the amount of 0.5–1.5% in the coal unprocessed with surfactants. The concentration of such dust particles in the air space decreases almost 2 times due to the rapid sedimentation under the influence of gravitational forces. Taking into consideration the energy indexes of destruction by the explosion energy of the coal-rock massif processed by surfactants will allow us to ground the rational parameters of the new method for driving mine workings.

Practical value. The use of the proposed mechanism of softening a coal-rock massif under the action of surfactants will make it possible to develop new environmentally friendly ways of driving mine workings in the coal and ore mines.

Keywords: *coal-rock massif, hard rock, explosive destruction, dust fraction, surfactant*

Introduction. Development of a coal-rock massif in deep horizons of mines is complicated by the following factors. An increase of hardness (strength) of carbonaceous rocks is connected with the processes of lithification, diagenesis, petrographical composition change, in particular, the prevalence of quartz-bearing rocks, as well as the structural changes occurring in the enclosing coal strata under the influence of lithostatic pressure, namely: cataclase, including crushing, granulation and cracking of separate mineral grains or of local zones within the unit. When mining mineral resources using the explosion energy (drivage of capital and preparatory workings in a coal-rock massif), this factor leads to the formation of fine quartz (silicosis-hazardous) dust due to numerous defects (micro-cracks) found in the structure of the quartz grains at the contact "explosive – rock" [1] as well as of the pneumaconiosis-hazardous dust under the dynamic action on the coal bed.

Thus, with an increase of the depth of the coal-rock massif development, the cumulative effect of the above-enumerated factors leads to the growth of dust and gas contamination of the mine atmosphere and at the same time to the significant worsening of miners' working conditions.

The main sources of dust formation under the development of a rock massif in deep mines are drilling, blasting and loading operations, which respectively account for 50–60%, 30–40% and 10% of the dust formed in mine workings.

Dust suppression during drilling operations is currently carried out by the use of lateral and central flushing, and during loading operations – by the widespread irrigation of the broken rock. As for the blasting operations, the only anti-dust measure used in practice is active ventilation of the face. However, ventilation alone cannot serve as a radical means of dust control in mine workings.

In our opinion, the new perspective way to reduce the dustiness of the mine atmosphere is the use of the methods of explosive destruction, based on the purposeful reduction of the strength of the medium at the contact "explosive – rock", "rock cutting tool – rock" under the influence on the destroyable polymineral medium of surfactants.

The analysis of the studies carried out earlier. In the works [2–5], the results of studies on the destruction of rocks saturated with different types of surfactants have been provided. In particular, they give a detailed description of the kinetics of saturation of a rock massif with surfactants, the action of which is based on the adsorption decrease of the surface energy, which facilitates the formation of cracks. Also it has been shown that saturation of a destroyed medium with active solutions is determined by the activity and the nature of the porosity of rocks, their initial moisture content, the type of a surfactant solution, the stressed state of a massif and others. In addition, these works investigate the possibility of directional changes in the properties of the rock by saturating the medium destroyed by an explosion with the surfactant – the solution of SARMA, the chemical composition of which is not shown. Due to the reduction of the surface energy at the contacts of mineral grains under the action of the given surfactant, the strength of the rock decreases and the efficiency of their fragmentation by the explosion energy increases due to the purposeful change of the properties of the destroyed medium. It should be noted that these works do not study the mechanism of destruction of the polymineral medium, weakened by the influence of surfactants at the contact "explosive – rock", i.e. the data on the effect of surfactants on the mineral components forming the rock are absent.

Meanwhile, according to the experimental studies reflected in the work [5], the action of alkali, for example, of Na_2CO_3, decreases the strength of quartz 2 times. Thus, the use of the alkaline solutions in our experiments as surfactants makes it possible to reduce the strength of the quartz-bearing rocks in particular sandstones and consequently to modify the mechanism of their destruction by explosive loads.

Purpose – to investigate the effect of surfactants on the concentration of fine-dispersed dust fractions in the air space of the working area and the character of destruction of a coal-rock massif by the explosion energy to develop an environmentally friendly way of driving mine workings in the coal and ore mines.

Research tasks. To achieve this goal the following tasks have been planned and accomplished:

– To study the petrographical composition of a rock massif by using the microscopic method.

– To conduct a laboratory investigation of the character of destruction of rock and coal samples saturated with surfactants, by the explosion energy.

– To establish the basic granulometric characteristics, the mineral composition of fine-dispersed products of rock and coal destruction as well as the concentration of dust particles in the air.

– Using the optical method to study the shape of newly formed particles of rock and coal samples destroyed by the explosion as well as to conduct the comparative analysis of granulometric characteristics of fine-dispersed fractions to determine the features of destruction of a coal-rock massif saturated with different surfactants.

The methodology and results of the studies. To study the effect of the surface-active agents (surfactants) on the nature of destruction of the rock massif, the samples of rocks and coal having various degrees of diagenesis and coalification were selected in different regions of the Donetsk coal basin – Western Donbas, Central and Eastern Donbas.

In our paper, we present the results of the studies carried out on the samples of strong fine-grained sandstone and coal selected from the coal-rock massif of the mine PSP "Dniprovska mine" ("DFEK Pavlogradugol"). The coal samples of the strength $f = 2–3$ by Protodjakonov M. scale were selected from the coal bed $c_5^в$, and the samples of dark gray fine-grained sandstone of the strength $f = 14–15$ by Protodjakonov M. scale – from the main roof of the coal bed $c_{10}^в$, which was opened by the working in the direction of the collecting haulage drift №110U (PCZ-picket).

From the rock samples with the size of the rib ~350–400 mm, the models of a cubic form with the size of the rib 40±2 mm (3 models for each series) were cut by means of a diamond disc. In all the models, in the center of the facet (2/3 of its height) a blast cavity with a diameter of 5 mm was drilled, and around it, at a depth of 0.5 of the height of the model's facet the cavity imitating the face of the working with a diameter of 25 mm was drilled by the diamond crown. Besides, on these samples the cuts of 1.5 mm thick were made, from which petrographical sections for the study under the microscope of the mineralogical composition and structure of rocks destroyed by the explosion were made.

The study of the mineralogical composition and the structural features of dark gray sandstone, selected at the PSP "Dniprovska mine" ("DFEK Pavlogradugol"), revealed that its main minerals are represented by clastic quartz – 30–40% and fragments of feldspar (mainly fragments of acid plagioclase) – 50–55%. Secondary minerals are represented by clay minerals of kaolinite group, montmorillonite and mica – 5–10%. The degree of rounding the fragments constitutes 1–2 points (angular and rounded-angular). The correlation of the types of cement (cement of contact and cement of regeneration) is about 1:1. The rock structure is fine-grained, the size of grains varies from 10 to 1000 microns (fig. 1).

The high content of quartz in sandstones indicates that under their destruction by the dynamic loads (impact, explosion) a great amount of silicosis-dangerous fine dusts can be formed.

Coal seams of the mine "Dniprovska" are mainly represented by the coal of grade "G". The microstructure of the coal is characterized by the alteration of flat-lying ingredients of the coal matter – vitrain, fusain, clarain and durain – i.e. micro stratums of the capacity reaching from 0.5–1.0 to

1.0–3.0 mm. The micro stratums are divided by three systems of mutually perpendicular visible microcracks (natural surfaces of weakening the structural connections in the coal matter) into the fragments ranging in size from 50×50 microns to 100×100 microns.

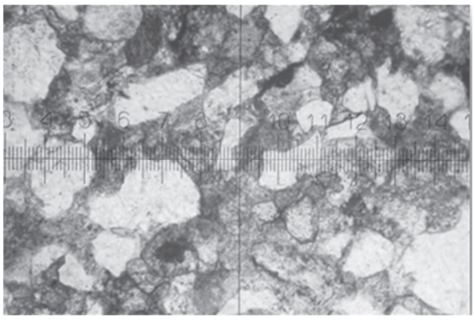


Fig. 1. The microphotograph of dark-gray sandstone. The section is transparent, an increase of magnification – 96×, passing polarized light (1 division of the measuring scale is 10 microns)

The prepared samples of the experimental series were placed for 24 hours in various surfactant solutions. Such alkaline solutions were used as surfactants: 10% sodium hydrogen carbonate *(NaHCO)₃,* 10% solution of soda ash *(Na_2CO_3)* and lime milk usually received by the dilution of one part of the burnt lime in 9 parts of water. In addition, one series of the experimental samples was saturated with magnetized water, prepared by passing the water through the normal household magnetizer. Control samples not subjected to the action of surfactants for 24 hours, were dried in the laboratory oven at a temperature of 50°C.

Then, a small charge of the high explosive PETN which were determined in the experimental way was placed in the explosive cavity of the model. The mouth of the charging cavity was sealed by stemming from the fine sand. Then the samples were put in a special explosion chamber [6] (fig. 2), the inner surface of which was lined with vacuum rubber. This camera was placed inside a semi-hermetic laboratory stand located on a special ground. On the top cover of the chamber, where allonges were fixed in the holes, clean filters AFA-VP, weighed on the analytical scales, were installed and the data on them were recorded in the journal of ex-perimental studies. Then the airline was formed by connecting with tubes the allonges, the filters, the electric aspirator EA-30 as well as the commutation of the explosive network and then an explosion of charges was performed with a blasting machine. After the explosion of the charge, the elektro-aspirator EA-30 was included in the model and within 30 minutes pumping of dusty air through the filters AFA-VP was carried out. After finishing the experiment, the filters were removed from the allonge, weighed on the laboratory's analytical scales and the data entered into the journal of experiments. Evaluation of the concentration of fine particles in the air medium was carried out by using a gravimetric method according to the formula

$$C = 1000 P_D / Q_a, \quad (1)$$

where $P_D = (m_1\text{-}m_2)$ – mass of the dust deposited on the filter after aspiration of the dusty air, mg/m^3; m_1, m_2 – mass of the filter before and after aspiration of the dusty air, mg; $Q_a = gt$ – volume of the air, m^3; g – productivity of the electrical aspirator EA-30 (30 l/min); t – time of aspiration, min.

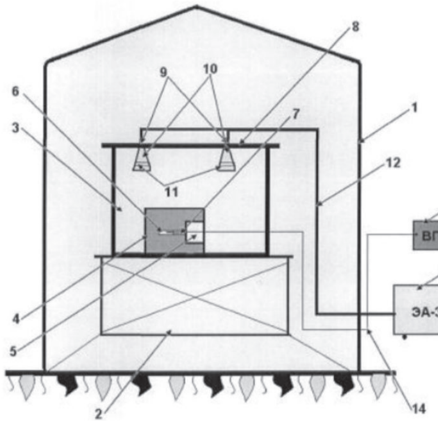


Fig. 2. The scheme of a laboratory stand for modeling the explosive destruction of rocks: 1 – a bunker; 2 – a platform for the samples and equipment; 3 – an explosion chamber); 4 – a model; 5 – a cavity of a working; 6 – an explosive charge; 7 – tamping; 8 – a cover of the explosion chamber; 9 – holes for allonges; 10 – allonges; 11 – filters AFA-VP; 12 – connecting tubes for pumping dusty air; 13 – a device for pumping dust (electric aspirator EA-30); 14 – an explosive network; 15 – a device for initiating explosive charges

The calculation results are presented in the form of dependences of the dust concentration on the type of the surfactant used to process the models of sandstone and coal (they are shown in fig. 3).

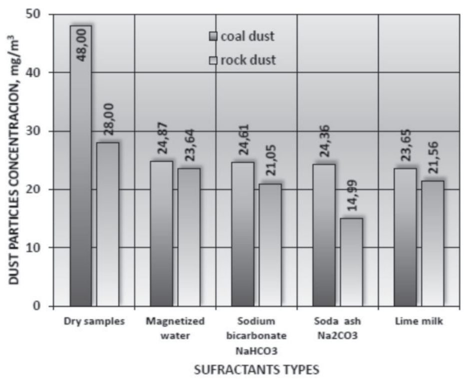


Fig. 3. The effect of types of surfactants on the concentration of dust particles in the air space of the explosion chamber

The analysis of the histogram provided in fig. 3 shows that by using the surfactants for processing the rock, hazardous on a dust factor (silicosis and pneumaconiosis), under their dynamic (explosive) destruction the concentration of fine-dispersed dust fractions in the air space of the explosion chamber is reduced almost twice.

Then, the destruction products were removed from the explosion chamber and divided into fractions by scattering them on a laboratory sieve with a size of cells from 50 to 400 microns, and the weight of each fraction was determined. The granulometric composition of the smallest dust fractions (of 0−100 microns) was further studied with the help of the polarizing microscope MP-2, equipped with lenses producing an increase of 20× and 40×, the integration table ISA and 8× oculars. This allowed determining the sizes of individual particles of the broken rock (grains and their fragments, mineral aggregates, etc.) within the accuracy of up to 1 micron under an increase of 240× or 480×. In addition, when increasing the magnification up to 480× it became possible based on characteristic optical constants to determine the mineralogical composition of dust-like fractions of sandstone and to analyze the shape of the particles for-med during the destruction of samples from a coal-rock massif.

Data on microgranulometry were processed by the method of approximation of experimental curves to two-parameter dependencies by using the standard program in the BASIC language. According to the sieve analysis, the histograms of fractional composition of the dust fraction (0−100 microns) were built in the automatic regime and the basic parameters of granulometry were determined: the average diameter of grains – d_{av}, their median size – *Md*, quartile size Q_{75} and Q_{25}, coefficients of uniformity of crushing – S_0 and asymmetry – S_k, calculated by the formulas

$$S_0 = \sqrt{Q_{75} / Q_{25}}\,; \qquad (2)$$

$$S_k = (Q_{75} \cdot Q_{25}) / Md^2\,. \qquad (3)$$

Below are the results of experimental studies on the destruction of the samples of sandstone and coal, weakened by the influence of surfactants.

Sandstone. Granulometric characteristics of the products of explosive destruction of sandstone saturated with various surfactants are shown in the table 1.

Table 1

Granulometric characteristics of the explosive destruction of sandstone products processed by surfactants

Surfactant	d_{av}, microns	Median and Quartiles, microns			S_0	S_k
		Md	Q_{75}	Q_{25}		
Dry samples	10.09	1.23	3.60	0.19	2.97	0.98
Magnetized water	12.32	1.96	5.65	0.66	2.94	0.98
10% solution of $NaHCO_3$	13.43	2.12	8.57	1.03	2.90	0.97
10% solution of Na_2CO_3	19.64	5.11	14.64	1.74	2.91	0.97
Lime milk	17.36	4.56	12.94	1.57	2.92	0.98

The analysis of granulometric characteristics of the destruction products, weakened by the influence of surfactants, shows that magnetized water (pH = 7) does not significantly affect the nature and mechanism of the explosive destruction of the given polymineral rocks. Perhaps under the action of the magnetized water some reduction in the strength of the sample occurs – in the character of destruction it is displayed in the slight increase of the average diameter of fine-dispersed particles (about 15−17%) in comparison with the fine-dispersed of dry (control) samples. In the products of sandstone destruction (fig. 4) the fine-dispersed fraction (0−100 microns) is presented by the exclusively acuteangled fragments of mineral quartz (90−95%), which suggests that destruction of the given rock by explosive loads mainly occurs by numerous defects in the grains of quartz.

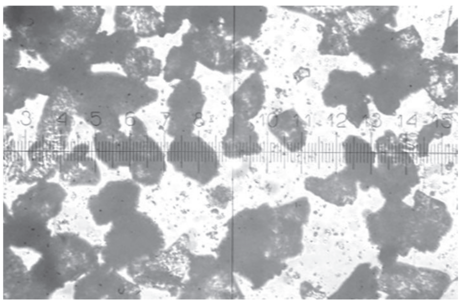


Fig. 4. The microphotograph of acute-angled fragments of quartz particles in the products of the explosive destruction of hard sandstones. An increase in magnification – 240× (1 division of the measuring scale is 5 microns)

These defects are observed in the field of vision of the microscope in the form of the strips of gas bubbles – planes of gas-liquid inclusions (GLI).

This fact is confirmed by the assessment of the newly formed fragments by the degree of their roundness. It is in the range of 0−1 points (acute-angled and angled), while initially (in the section) the degree of roundness of mineral particles composing the sandstone, is 1−2 (angular and rounded-angular).

Saturation of the sandstone samples with the 10% solution of sodium bicarbonate *($NaHCO_3$)* leads to the fact that the character of the polymineral rock destruction changes under the action of explosive loads.

In particular, the average diameter of fine-dispersed dust fractions of 0−100 microns increases 1.33 times (compared with dry samples). The morphological study of the fragments under the microscope showed that the newly formed surfaces at the contact “explosive – rock” are formed both at the contacts of grains of minerals and the defects of their structure (the GLI planes in the grains of quartz and the cleavage planes in the grains of feldspars) and in the ratio of the contact “grain – grain” the GLI plane is about 4 to 1.

Under the action of the 10% solution of soda ash *(Na_2CO_3)* on the strong sandstones, the nature and mechanism of the explosive destruction of the polymineral rocks, containing about 40% of clastic quartz in its composition, varies considerably. The average diameter of the fine-dispersed particles increases almost twice: 10.09 microns – dry samples, 19.64 microns – sandstone samples processed with the soda ash solution having a much stronger alkaline reaction compared with the sodium bicarbonate solution.

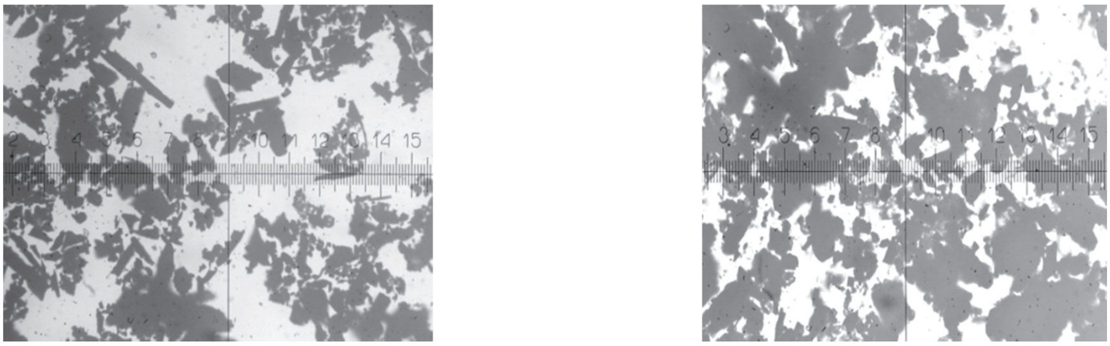
The morphological analysis of the fine-dispersed fraction of 0–100 microns, performed under the microscope at an increase of magnification of 480×, helped to establish that the newly formed by the explosion planes develop only on the contacts of grains.

Coal. The exposure of magnetized water and lime milk to the 10% solutions of $NaHCO_3$ and Na_2CO_3 leads to an increase of the mean diameter of the fine-dispersed products of the explosive coal destruction (the fraction is of 0–100 microns) 2 times on average as compared with the unprocessed surfactant samples (fig. 5). At the same time the chemical composition and pH of the solutions do not affect the size of dust particles (table. 2).

In this case, apparently, the effect of P.A. Rebinder is displayed [5], which causes the adsorption reduction of the coal strength at the expense of decreasing the interfacial surface at the penetration of solutions into microcracks.

It should be noted that in the pulverized destruction products of the coal samples processed by magnetized water and also 10% food and soda ash solutions, in a minor amount, the fragments of quartz grains which usually do not exceed 1–3% (fig. 6, *a*) are present.

In the products of the explosive destruction of coal processed with lime milk, the quartz grains are absent (fig. 6, *b*). In this case, the mineralogical composition of the coal destruction products can be explained by the fact that under a high temperature of the explosion of the charge, lime milk is converted into mixtures of calcium oxides and calcium carbonate, which reacting with the fine-dispersed particles of quartz, form calcium silicates in the form of large, fast settling units under the influence of the gravitational forces.



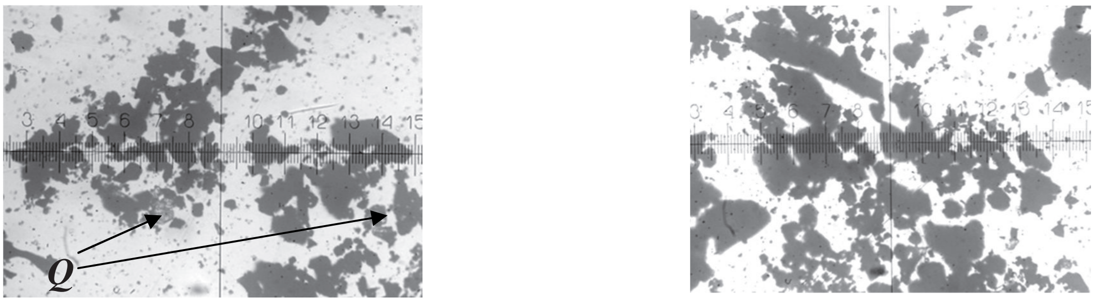
a *b*

Fig. 5. The microphotograph of fragments of the smallest particles in the products of explosive destruction of the coal selected from the coal seam $c_5^{в}$ of the Dniprovska mine in dry samples (a) and after the effect of surfactants (b). An increase of magnification 240× (1 scale division is 5 microns)

Table 2

Granulometric characteristics of the explosive destruction of coal products processed by surfactants

Surfactant	d_{av}, microns	Median and Quartiles, microns			S_0	S_k
		Md	Q_{75}	Q_{25}		
Dry samples	14.93	3.29	9.24	1.14	2.85	0.95
Magnetized water	29.40	15.41	34.35	5.81	2.43	0.84
10% solution of $NaHCO_3$	29.47	15.52	34.70	5.85	2.44	0.83
10% solution of Na_2CO_3	29.84	15.69	34.87	5.92	2.42	0.84
Lime milk	30.67	16.12	35.85	6.17	2.43	0.84



a *b*

Fig. 6. The microphotograph illustrating the presence of quartz (Q) in the pulverized destruction products of the coal bed $c_5^{в}$ *(a) before and after their processing with lime milk (b). An increase of magnification 240× (1 scale division is 5 microns)*

Conclusions. Under the explosive destruction of the samples of strong dark gray sandstone and coal selected from the Dniprovska mine (PJSK "DFEK, Pavlogradugol"), with the purposeful reduction of their strength by saturating them with surfactants, having an alkaline reaction, the following conclusions were made.

In sandstones unprocessed with surfactants the newly formed fracture surfaces are mainly formed by the defects in the structure of quartz within the grain.

In sandstones saturated with alkaline solutions of surfactants, where the content of the mineral quartz exceeds 40%, the change in the failure mechanism takes place at the micro level, while the newly formed surfaces are formed at the contacts of quartz grains with other rock-forming minerals.

With a decrease in the strength of sandstone and coal, due to the action of surfactants, the average diameter of fine particles formed at the contact "explosive – rock" increases.

When saturating coal with lime milk, in the destruction products the diameter of fine particles increases and, moreover, the fragments of quartz grains are absent.

Thus, to reduce the strength of a coal-rock massif, the most effective surfactants, as it was established by our study, are soda ash for hard rock and lime milk for coal.

Therefore, the change of the mechanism of the coal-rock massif destruction promotes the reduction of the dependence of the personnel on the occupational diseases such as silicosis, anthracosis, pneumaconiosis and pulmonary fibrosis. This is achieved at the expense of rapid settling of dust particles under the influence of gravitational forces as well as concentration of quartz-bearing dust fractions in the atmosphere of the mine working formed under the explosive breaking of rocks. The use of such approaches contributes greatly towards safety of mining operations. It is the basic requirement for the development of resource-saving and environmentally friendly ways of breaking hard and tense rocks by the explosion when driving mine workings in the coal and ore mines.

References / Список літератури

1. Yefremov, E.I., Petrenko, V.D. and Kratkovskiy, I.L. (1993), "On the effect of the fractional composition of quartz-bearing rocks on the content silicosis-hazard dust in the products of their destruction", *Doklady AN Ukrainy*, no.5, pp. 45–49.

О влиянии фракционного состава кварцсодержащих пород на содержание силикозоопасной пыли в продуктах их разрушения / Э.И. Ефремов, В.Д. Петренко, И.Л. Кратковский, С.В. Шевченко // Доклады АН Украины. – 1993. – № 5. – С.45–49.

2. Synbulatov, V.V. (2005), "Directional change of the deformation characteristics of rocks with the surface-active substances", Proceedings of the "Ural Mining decade April 4–14, 2005", UNU, Yekaterinburg, pp. 19–20.

Сынбулатов В.В. Направленное изменение деформационных характеристик горных пород поверхностно-активными веществами: материалы Уральской горнопромышленной декады 4–14 апреля 2005г. / В.В. Сынбулатов – Екатеринбург: УНУ, 2005. – С. 19–20.

3. Zhilin, A.S. (2003), "Use of surfactants to improve the quality of rock crushing", *Zapiski Gornogo Instituta*, Is. 155, part 2, St. Petersburg, pp. 62–65.

Жилин А.С. Использование поверхностно-активных веществ для повышения качества дробления горных пород / А.С. Жилин // Записки горного института – СПб., 2003. – Т.155. – Ч. 2. – С. 62–65.

4. Doludareva, Ya.S. (2012), "Influence of surfactants to modify the strength characteristics of rock", *Suchasni Resursozberihaiuchi Tekhnolohii Hirnychoho Vyrobnytstva*, Vol. 1, Kremenchug, pp. 8–16.

Влияние поверхностно-активных веществ на изменение прочностных характеристик горных пород / Я.С. Долударева [и др.] // Сучасні ресурсоенергозберігаючі технології гірничого виробництва. — Кременчук, 2012. – Вип. 1. – С. 8–16.

5. Efremov, E.I., Kratkovsky, I.L. and Ishchenko, K.S. (2013), "Influence of surfactants on the nature of the dynamic fracture polyminerals rock", *Rozrobka Rodovyshch 2013*, NMU, Lizunov Press Ltd., Dnipropetrovsk, pp. 229–234.

Ефремов Э.И. Влияние ПАВ на характер динамического разрушения полиминеральных горных пород / Э.И. Ефремов, И.Л. Кратковский, К.С. Ищенко // Розробка родовищ 2013: науково-технічний збірник ДВНЗ „НГУ" – Днепропетровск: ТОВ Лізунов Прес, 2013. – С. 229–234.

6. Holinko, V.I., Lebedev, Ya.Ya. and Saveliev, D.V. (2014), Patent No. 91043 of Ukraine IPC7 F42D 3/04. "A method of modelling the explosive rock breaking", patentee: National Mining University, No. u201312830; application date November 4, 2013; publication date June 25, 2014, Bulletin no.12.

Пат. № 91043 Україна МПК F42D 3/04 Спосіб моделювання вибухового руйнування гірських порід / В.І. Голінько, Я.Я. Лебедєв, Д.В. Савельєв [та ін.]; заявник і власник патенту ДВНЗ „НГУ". – № u201312831 від 04.11.2013. – Опубл. 25.06.2014; Бюл. № 12.

Мета. Дослідження впливу поверхнево-активних речовин (ПАР) на концентрацію дрібнодисперсних пилоподібних фракцій у повітряному просторі робочої зони та характер руйнування вуглепородного масиву енергією вибуху для розробки екологічно безпечного способу проходки гірничих виробок на вугільних і рудних шахтах.

Методика. Проведено декілька серій експериментальних досліджень у лабораторних умовах з оцінки впливу ПАР на концентрацію дрібнодисперсних частинок у повітряному середовищі та характер руйнування міцних гірських порід і вугілля вибухом за допомогою розробленого способу моделювання та стенда для його реалізації. З використанням оптичного методу, що включає поляризаційний мікроскоп з інтегратором, вивчена мікроструктура та гранулометричний склад пилоподібних частинок порід і вугілля, насичених ПАР.

Результати. Представлені експериментальні дослідження з оцінки впливу ПАР на концентрацію дрібнодисперсних частинок у повітряному середовищі та характер руйнування міцних гірських порід і вугілля енергією вибуху. Аналіз продуктів руйнування оптичним

методом дозволив встановити, що уламки найдрібніших частинок, наприклад, міцного дрібнозернистого пісковика (f =14–15), відібраного з основної покрівлі вугільного пласта c_{10} при проходці збірного штреку № 110У, ПК3, шахти „Дніпровська", „ДТЕК-Павлоградвугілля" й оброблених ПАР, представлені кварцовими зернами (90 –99%) округлої форми, а необроблених – гострокутними уламками. За даними масових вимірювань дрібнодисперсних частинок у продуктах руйнування міцних пісковиків і вугілля, оброблених 10% розчинами бікарбонату натрію ($NaHCO_3$) і кальцинованої соди (Na_2CO_3), омагніченою водою та вапняним молочком, встановлені їх гранулометричні характеристики – медіанний та квартільні розміри, коефіцієнт сортування та асиметрії. Розраховані чисельні значення концентрації пилоподібних фракцій у повітряному просторі в залежності від типу застосовуваних поверхнево-активних речовин.

Наукова новизна. З використанням розробленого способу моделювання руйнування гірських порід, оброблених ПАР, встановлено, що середній розмір частинок фракції 0–100 мкм збільшується в 1,2–1,9 рази. У продуктах руйнування зразків вугілля, оброблених вапняним молочком, відсутні уламки кварцу, що в кількості 0,5–1,5%, зазвичай, присутні в необробленому ПАР вугіллі. Концентрація таких пилоподібних частинок у повітряному просторі знижується майже у 2 рази за рахунок швидкого осідання під дією сил гравітації.

Практична значимість. Використання запропонованого механізму знеміцнення вуглепородного масиву дією ПАР дозволить розробити нові екологічно безпечні способи проходки гірничих виробок на вугільних і рудних шахтах.

Ключові слова: *вуглепородний масив, міцні гірські породи, вибухове руйнування, пилоподібні фракції, поверхнево-активні речовини*

Цель. Исследование влияния поверхностно-активных веществ (ПАВ) на концентрацию мелкодисперсных пылевидных фракций в воздушном пространстве рабочей зоны и характер разрушения углепородного массива энергией взрыва для разработки экологически безопасного способа проходки горных выработок на угольных и рудных шахтах.

Методика. Проведено несколько серий экспериментальных исследований в лабораторных условиях по оценке влияния ПАВ на концентрацию мелкодисперсных частиц в воздушной среде и характер разрушения прочных горных пород и угля взрывом с помощью разработанного способа моделирования и стенда для его реализации. С использованием оптического метода, включающего поляризационный микроскоп с интегратором, изучена микроструктура и гранулометрический состав пылевидных частичек пород и угля, насыщенных ПАР.

Результаты. Представлены экспериментальные исследования по оценке влияния ПАВ на концентрацию мелкодисперсных частичек в воздушной среде и характер разрушения крепких горных пород и угля энергией взрыва. Анализ продуктов разрушения оптическим методом позволил установить, что обломки мельчайших частичек, например, крепкого мелкозернистого песчаника (f = 14–15), отобранного из основной кровли пласта c_{10} при проходке сборного штрека №110У, ПК3, шахты „Днепровская", „ДТЭК Павлоградуголь" и обработанных ПАВ, представлены кварцевыми зернами (90–99%) округлой формы, а необработанных – остроугольными обломками. По данным массовых измерений мелкодисперсных частичек в продуктах разрушения прочных песчаников и угля, обработанных 10% растворами бикарбоната натрия *($NaHCO_3$)* и кальцинированной соды *(Na_2CO_3)*, омагниченной водой и известковым молочком, установлены их гранулометрические характеристики – медианный, квартильные размеры, коэффициент сортировки и асимметрии. Рассчитаны численные значения концентрации пылевидных фракций в воздушном пространстве в зависимости от типа применяемых поверхностно-активных веществ.

Научная новизна. С использования разработанного способа моделирования разрушения горных пород, обработанных ПАВ, установлено, что средний размер частиц фракции 0–100 мкм увеличивается в 1,2–1,9 раза. В продуктах разрушения образцов угля, обработанных известковым молочком, отсутствуют обломки кварца, которые в количестве 0,5–1,5% обычно присутствуют в необработанном ПАВ угле. Концентрация таких пылевидных частиц в воздушном пространстве снижается почти в 2 раза за счет быстрого оседания под действием сил гравитации.

Практическая значимость. Использование предложенного механизма разупрочнения углепородного массива действием ПАВ позволит разработать новые экологически безопасные способы проходки горных выработок на угольных и рудных шахтах.

Ключевые слова: *углепородный массив, крепкие горные породы, взрывное разрушение, пылевидные фракции, поверхностно-активные вещества*

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